(2)

A MILITARY DATABASE AND ITS APPLICABILITY TO EARTH SCIENCE RESEARCH*

Gary L. Angelici
Sterling Software, NASA Ames Research Center
Moffett Field, California, USA

Edwin J. Sheffner
Johnson Controls World Services, NASA Ames Research Center
Moffett Field, California, USA

ABSTRACT

In the 1980's, the United States Air Force developed a database of collected and generated data for the conterminous United States, with emphasis on the western portion of the country. The 180 gigabyte GMIS (Geographical Management Information System) includes several data sets, such as Landsat satellite imagery and Digital Elevation Models, commonly used in earth science research and applications. Also included are specialized landscape data sets collected for selected small sites. With declassification in 1992, the GMIS was released by the Air Force to the NASA Ames Research Center. Portions of the database have already been evaluated and/or used for a wide variety of applications, from ecosystem science modeling requiring elevation data to visualization technique development using Landsat data. The greatest applicability of GMIS, however, may be found in site studies which investigate how many variables, such as vegetation, landform, geology, and transportation, interact to form a landscape.

1.0 INTRODUCTION

With the decline in tension between the United States and the former Soviet Union, many databases have become artifacts of the Cold War and are being made available for non-classified work. These largely high quality, rich bodies of information, developed with substantial funding, can be a "peace dividend" to a variety of non-military applications. Potentially valuable to large and small efforts, these databases need to be evaluated to determine their ability to satisfy the requirements of earth science research and applications.

In this paper, one such former military database is reviewed for its ability to provide data for earth science research. First, we present a description of the background and contents of the GMIS (Geographic Management Information System), developed by the United States Air Force and now stored at the NASA Ames Research Center (ARC). Second, the applicability of the database in earth science research is then evaluated for potential use by an earth science project. The background and data requirements of a proposed ecosystem science project are described and followed by a determination by investigators of the usefulness of GMIS data sets for the large project. Finally, the usefulness of the database for earth science research is then explored with a description of actual experiences of GMIS data use and a discussion about potential applications that the database may have for future research.

2.0 GMIS DATABASE OVERVIEW

2.1 GMIS DATABASE BACKGROUND

The United States Air Force, through the Ballistic Missile Organization at Norton Air Force Base, California, developed the GMIS in the 1980's in support of various ICBM (Inter-Continental Ballistic Missile) siting and environmental studies. The GMIS contains both raster and vector format data for the conterminous United States, with emphasis on the western United States. The GMIS was manipulated by the Air Force using IDIMS (Interactive

* Presented at the 25th International Symposium, Remote Sensing and Global Environmental Change, Graz, Austria, 4-8 April 1993.

Digital Image Manipulation System) image processing software and ARC/INFO geographical information system software on a VAX/VMS system. The Air Force also developed an on-line data catalog for GMIS consisting of a collection of relational tables that describe the location and content of the GMIS data (TRW, 1992).

Early in 1992, the Air Force declassified GMIS, phased out the program GMIS was compiled to serve, and stopped supporting the database. Through an agreement between the Air Force and NASA, one copy of the database was sent to the NASA Ames Research Center, where it currently resides. The agreement specified that NASA could use and distribute data sets in exchange for its storage and maintenance.

The GMIS data set was compiled so as to be able to select sites from a sub-continental sized area and to examine specific landscape characteristics of the selected sites in some detail and in relation to one another. Thus, for any selected site, of interest was the vegetation, land form, transportation network, sub-surface geology, population density, etc. and the manner in which those features interacted to form a landscape. The three dimensional aspect of the landscape was also of interest as was change in the landscape over time.

2.2 GMIS DATABASE CONTENTS

The 180 gigabyte GMIS contains a wide variety of acquired and derived raster and vector data sets. General categories of GMIS data are listed in Table 1 (TRW, 1989).

Table 1. General GMIS Data Categories

Terrain	Infrastructure	Environmental	Administrative	Other
Elevation	Power Lines	Weather	National/State Parks	Satellite Imagery
Hydrology	Pipe Lines	Biology	Indian Reservations	Topographic Maps
Geology	Roads	Wilderness Areas	Military Installations	Planemetric Maps
Minerals	Bridges	Wildlife Refuges	Urban Areas	
Geothermal Resources	Railroads	Cultural Resources	Census Data	
Soils Data	Aqueducts		Congressional Districts	
Land Use/ Land Cover			State/County Boundaries	
			World Database III	

Image data sets include Landsat TM (Thematic Mapper) and MSS (Multispectral Scanner) and SPOT (System Probatoire de la Terre) data. Other raster data sets commonly used in earth sciences research include 1:24000 and 1:250000 scale DEM (Digital Elevation Models), and DMA (Defense Mapping Agency) elevation data. GMIS DLG (Digital Line Graph) data consists of road, railroad, and pipeline data at the 1:100000 scale and all overlays (including hydrology) at the 1:2000000 scale. The chart in Table 2 (TRW, 1992) shows the spatial and temporal extents of the most common data sets, as well as the number of magnetic tapes in the database for each. The format for each common data set is the format, familiar to most earth resources analysts, supplied by the data provider.

Table 2. GMIS Data Inventory for Common Data Sets

Data Set	Spatial Extent	Temporal Extent	Entries
Landsat TM	Selected Western U.S.	Aug82-Oct87	172
Landsat MSS	Western U.S.	Jul74-Oct83	520
SPOT	Unknown	Oct86	2
DEM (1:24000)	Selected Western U.S.	-	243
DEM (1:250000)	U.S.	-	973
DMA	U.S.	-	307
DLG (1:2000000)	U.S.	-	22
DLG (1:100000)	U.S.	-	6279

While these data sets are the primary components of the GMIS, there are other data which were generated for use by the Air Force. One example of these is a geologic map of the western United States in a raster format. But, since the GMIS was created to investigate extensively the characteristics of specific sites, there are a number of specialized data sets for these sites. Although only a small fraction of these data sets have been viewed by earth resources analysts, the data catalog reveals that most are in ARC/INFO "export" format and many are based on USGS quadrangles. A small sample of these data sets are listed by general category in Table 3.

Table 3. Specialized GMIS Data Sets

Soils/Vegetation	Geologic	Ecosystem	Administrative/Cultural
Soil Properties	Geologic Map	Wetlands Cultural Biology	Population Density
Soil Samples	Geologic Block Models	Aquifers	Land Use
Soil Terrain	200' Depth to Rock	Environmental Impact Statements	Rail Ownership
			Rail Networks
			Route Listing

Most of these specialized data sets are located around particular sites in the western United States and were sampled in the middle to late 1980's. Many sites were studied intensively, with a full complement of resulting data. Environmental impact statements had to be submitted because of the data collection being performed.

3.0 APPLICATION OF GMIS TO AN EARTH SCIENCE PROJECT

3.1 OTTER II PROJECT

The Oregon Transect Ecosystem Research (OTTER) II project has been proposed to study carbon dioxide assimilation and water and carbon dioxide fluxes under varying climatic and disturbance regimes. Models will be executed on data over three resolutions, considering additional parameters (such as disturbance) as the resolution increases from 1 kilometer to 100 meters to 30 meters. The data at each scale will be co-registered to a UTM (Universal Transverse Mercator) projection map base.

The models will process data for the entire state of Oregon (250,000 square kilometers) at 1 kilometer resolution, over a 10,000 square kilometer area at a 100 meter resolution and over selected small sites at a 30 meter resolution. As can be seen, a large volume of data must be obtained in order to conduct this study. Large scale AVHRR (Advanced Very High Resolution Radiometer) data has been chosen as the imagery for use at low resolution. Table 4 shows the data sets that must be obtained to satisfy the data requirements of the OTTER II project.

Table 4. OTTER II Data Requirements (By Resolution)

Low Resolution (1 km)	Medium Resolution (100 meter)	High Resolution (30 meter)
AVHRR	Landsat MSS	Aircraft Data
DEM Data (1:250000)	DEM Data (1:250000)	DEM Data (1:24000)
Soils (1:250000)	Soils (1:250000)	Soils (1:24000)
DLG Data	DLG Data	DLG Data
		Gauged Watersheds
		Timber

It is expected that a large portion of the data, particularly the AVHRR and aircraft data required for the project will come from the OTTER I project, which collected a variety of remote sensing image and field data for six sites in west central Oregon in 1990. The DLG data will be used mainly in delineating watersheds for the hydrological component of the ecosystem model. Other DLG data may be used for road overlays in output ecosystem maps.

3.2 APPLICATION OF THE GMIS TO OTTER II

The main categories of GMIS data that were reviewed for their potential value to the data requirements of the OTTER II project were the satellite remotely sensed imagery, elevation data, DLG data, and soils data. When investigators learned of the acquisition dates of the Landsat MSS data available in the GMIS, 1983 at the latest (see Table 2), they felt that comparisons with the 1990 aircraft data could not be reliably made. More recently-acquired Landsat MSS data had to be obtained. The possibility of using Landsat TM for the high resolution scale was dispatched when it was discovered that there were no TM data in the GMIS covering the Oregon sites.

Elevation data were seen to be the most valuable data set in the GMIS database for the OTTER II project. The GMIS data catalog revealed that all 1:250000 scale DEM quadrangles for the state of Oregon were available. Thus, the project needs for low and medium resolution elevation data could be met by the GMIS database. Although 1:24000 scale DEMs have not even been created for many areas of Oregon, the catalog was queried for the Oregon sites requiring high resolution elevation data. The search revealed no high resolution elevation data for the west-central area of Oregon.

Another area of potential application is the GMIS DLG data, including hydrology data at 1:2000000 scale and road data at 1:100000 scale. The scale of the hydrology data is seen by investigators as insufficient for use in the watershed modeling executions. The road data may be used as overlays in the final presentation products of the project, but is not seen as valuable data for the ecosystem investigations.

The soils data in the GMIS (e.g., terrain, sample) may have been useful to the OTTER II project had the data been available over the state of Oregon. None of the sites with soils data in the GMIS were in Oregon. It is possible that the soils data sets in the GMIS may be useful for projects selecting the sites targeted by the GMIS.

4.0 APPLICATION OF GMIS DATABASE TO EARTH SCIENCE

4.1 EXAMPLES OF ACTUAL GMIS DATA USE

To date, there have only been a few actual attempts to utilize any of the data sets from the GMIS database. These applications have typically been the integration of one or two files from the database with a larger complement of data to provide an additional data layer. An example would be a graduate student at the University of Montana who required a 1:250000 scale quadrangle of DEM data for a site in central Oregon as part of an ecosystem research project. Since these data are in a common format, there were no problems in utilizing these data for his purposes. The experiences of two somewhat larger efforts, which have had varying success in applying these data, illustrate the range of applications that can be accommodated by this database.

4.1.1 Geologic Map

A potential user of the GMIS database wanted to incorporate a file from the GMIS, a digitized geologic map of the western United States, as one data layer in geographic information system (GIS) on hydrology. The file was located, loaded from tape on a VAX 11-785, and displayed using software from a commercial image processing package. The display revealed that the data had been "packed," i.e. written in a format to conserve disk storage space, using software written by the contractor staff at Norton Air Force Base. The packing routine loaded the number of lines, samples, data type and checking code into the first 10 byte locations of a 2048 byte long record. Then, the number of consecutive equal pixels was counted. When a different pixel value is found, the pixel count and value are output, depending on the input image type.

A routine to "unpack" the data was also written by the contractor staff. The FORTRAN code, in hard copy format, was obtained from Norton Air Force Base and converted into a disk file on the VAX 11-785. Attempting to compile the code revealed the absence of a sub-file containing variable type definitions. Norton staff was unable to find a copy of the sub-file, and the unpacking of the data is currently awaiting the re-creation of the sub-file or the substitution of equivalent information.

4.1.2 Landsat Visualization

The Computational System Research Branch at ARC is working with the GMIS to develop new algorithms and procedures for visualization of data from very large data sets. Two study sites are currently being examined: Death Valley, California and the Seeley/Swan region of Montana. These sites were selected at the request of scientists on the ARC staff who are working in the sites and who feel that three dimensional modeling of the "raw data" and the derived data will aid their analyses. Multiple Landsat scenes were required for each site. Satellite data and corresponding digital terrain models from both sites have been located in the GMIS database, and efforts are now underway to digitally mosaic the satellite data and register it to the terrain model. Development of procedures for remote access and "fly-through" of the data will follow. The primary difficulty to date has been locating and applying appropriate software to do some of the routine data manipulations, e.g. digitally mosaicking Landsat scenes.

4.2 POTENTIAL APPLICATIONS OF THE GMIS DATABASE

The nature of the data included in the GMIS makes the database of potential value in studies ranging from large scale ecological processes to the development of data visualization techniques for very large data sets.

The database is of particular value in studies requiring moderate spatial and spectral resolution satellite imagery, three dimensional landscape analysis, and the location of cultural features, especially transportation networks. Beyond the intrinsic value in the database, the imagery can provide a baseline for change detection studies when it is augmented with current year data, or it can provide an additional data point for studies that include older and more recent Landsat acquisitions.

In the current research environment in the earth sciences, global change issues are of major concern. Fundamental biophysical processes are being examined at the local level, but they must also be understood and monitored at regional and global scales. Satellite imagery is potentially ideal for such tasks, but efforts have only begun to integrate data from satellite systems with different spatial resolution. These efforts have been hampered, in part, by the cost of acquiring the very large data sets needed for algorithm development and testing. The size and availability of the GMIS data set make it suitable and advantageous for use as one element in a system to link sensors with different spatial resolution. If the GMIS MSS coverage is combined with coverage from sensors with finer and coarser resolution it could serve as part of a test bed for the development of algorithms that will, interactively, store, retrieve, and display data of varying spatial resolution.

5.0 CONCLUSIONS

A few experiences with and observations about the GMIS database have revealed its spatial breadth, covering most of the conterminous United States. Selected GMIS data sets have assisted investigators in their research which uses only a small percentage of the data available. And these data sets are the ones most commonly used by the earth science research and applications community.

The full usability of the GMIS database, however, is yet to be discovered. As familiarity with the specialized data sets within GMIS increases, new endeavors in earth science research may be conducted to take full advantage of the depth of data that exists at selected sites. We feel that the most important applications will exploit the rich data sets which can be used to show how many ecological variables interact to form a landscape. Further investigation into the nature of these data sets and their applicability to earth science research still needs to be accomplished. Until the data set is explored for its full potential, its usefulness cannot be accurately evaluated.

If it can be demonstrated that comprehensive databases developed for the military but which contain data relevant to earth science are, in fact, of value in earth science research, the benefit to both the military and earth science communities would be substantial. In addition, with worsening environmental problems throughout the world, every tool which can be used to increase the ability of the scientific community to understand earth processes must be applied.

6.0 REFERENCES

TRW, Inc. (1989), Geographic Management Information System (GMIS) Database Design Document, U.S. Department of the Air Force, Norton Air Force Base, CA.

TRW, Inc. (1992), Geographic Management Information System Data Catalog, U.S. Department of the Air Force, Norton Air Force Base, CA.